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EFFECTS OF SURFACE TREATMENTS  
ON BONDING TO POLYETHYLENE  
WITH VARIOUS TYPE ADHESIVES

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OCTOBER 1967

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by

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## OBJECT

To investigate the influence of surface treatments on the joint strengths of adhesive-bonded polyethylene when using various type adhesives.

## SUMMARY

Six surface treatments were investigated to determine what benefits they afforded in adhesive bonding to polyethylene. Three different types of polymeric adhesive systems—epoxy, polyester, and nitrile-phenolic—were used with each surface treatment in order to make a better assessment of the treatment and to determine if the same relative results were obtainable within each adhesive system.

## CONCLUSIONS

1. Best overall bonds were obtained with the epoxy adhesive.
2. In all cases, the surface treatments used prior to bonding resulted in improved bond strengths over the untreated control.
3. The effectiveness of the surface treatments tested, in descending qualitative order, are as follows:
  - a. Flame treated
  - b. Acid treated, rinsed, acetone dried
  - c. Acid treated, rinsed, wiped and air dried at 23°C
  - d. Acid treated, rinsed, oven dried at 71°C
  - e. Acid treated, rinsed, oven dried at 90°C
  - f. Sanded.

## RECOMMENDATIONS

When bonding polyethylene, some form of surface treatment capable of producing a more "wetable" surface for the adhesive is desirable. Surface treatments such as those covered in this investigation should be used, depending on the requirements of the application.

Flame treating is fast and produces bond strengths greater than any other treatments covered in this investigation. However, this process requires very careful

control, without which heat warpage can result. This method is simplest to use by the average person on pieces of thick cross section, whereby the danger of heat warpage is minimized.

Acid treating, followed by either acetone or air drying after wiping, is a surface treatment which produces strong bonds and is recommended where speed is not a factor or where complex geometrical surfaces are involved.

Sanding is a simple treatment which is useful where speed is essential and not much strength is required.

## INTRODUCTION

Polyethylene has a variety of uses as an engineering plastic. Its excellent resistance to chemical and corrosive attack, its electrical properties, low water absorption, and its ease of fabrication by such methods as extrusion and injection molding contribute to its versatility.

There are many areas where adhesive bonding of polyethylene offers useful and practical advantages over mechanical joining methods. One of the principal problems in bonding polyethylene, however, is the difficulty of wetting its glossy, wax-like nonpolar surface. Since surface wetting is a prime requisite for obtaining a good adhesive bond, some means must be employed to increase the surface free energy of polyethylene before bonding.

This investigation was intended to evaluate several surface treatments on polyethylene aimed at improving adhesive bond strengths. The results reported here should be used as a guide when considering surface treatments in subsequent adhesive bonding applications of polyethylene. Permanence tests will have to be employed, of course, to determine the effects of long time aging and environment prior to application where these effects must be taken into consideration.

## DISCUSSION

This study was undertaken in connection with a classified project where glass was being bonded to polyethylene. Three adhesives, an epoxy, a polyester, and a nitrile-phenolic rubber had been evaluated for resistance to hot Freon 113. The epoxy and the polyester had been essentially unaffected by the hot Freon while the nitrile-phenolic increased in weight slightly. These were the adhesive systems evaluated for bonding to polyethylene in this investigation.

The flame treating and acid treating surface preparations of the epoxy bonded group produced bonds so strong that failure always occurred in the adherends upon application of load (see Table 1, p 7). Only the sanded epoxy specimens and the control failed adhesively, with the sanded specimens failing at approximately  $3\frac{1}{2}$  times the failing load of the control.

In the polyester group differences in surface treatments become evident. The flame-treated polyester specimens failed in the adherend (434 psi, calculated), as did the flame-treated epoxy specimen (480 psi). Since the bond strength values shown here are calculated, i.e., they are based on a 0.5-square-inch bonding area, obviously the failing loads for the adherends are only one-half the values



discussed here and shown in Table 1. Some adhesive failure in the acid-treated, acetone-dried specimens (394 psi) and acid-treated, wiped and air-dried specimens (357 psi) is apparent. The acid treated, oven-dried specimens all failed adhesively at approximately equal loads. The sanded specimens here were about twice as strong as the unsanded controls. The controls were again, as expected, well below the others at a failing load of 85 psi.

The nitrile-phenolic proved to be a considerably poorer adhesive than the epoxy and polyester systems, but still pointed up the effectiveness of flame treatment. The flame-treated nitrile-phenolic specimens failed at 138 psi. The acid treated, acetone dried; acid treated, wiped, and air dried; and acid treated, oven dried (71° and 90°C) failed at 112 psi, 110 psi, 108 psi, and 96 psi respectively. Sanded specimens failed at 56 psi and the control at 44 psi.

Regardless of the adhesive used, it is evident that the untreated control yielded bond strengths below each of the surface treated specimens, well below all but the sanded nitrile-phenolic specimens.

Pliobond, the solvent-type, nitrile-phenolic thermoplastic adhesive used in this study, has the usual disadvantage of solvent-type adhesives in bonding nonporous materials. The solvent, which must evaporate to effect a "cure," is trapped and can only migrate out slowly through the edges. Heating only expands the solvent as a gas, which creates large unbonded areas. Generally speaking, solvent-type adhesives are undesirable for such applications since results can vary greatly, depending upon the temperature and humidity of the atmosphere during application, open time of the adhesive-coated adherends, film thickness, and curing conditions.

Flame treatment proves to be superior to all other surface treatments tested in spite of the fact that the edges of the treated specimens were warped and the mating pieces did not seat properly. Proper controls can usually be effected to meet production requirements.

Sanding increases the surface available for bonding but does not chemically alter the surface in any way. It is interesting to note that if only a slight increase in bond strength is required, sanding may be considered as a quick, inexpensive means to alter the surface.

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## **Preparation of Test Specimens**

### **General**

The polyethylene used in this investigation was a pigmented, high density, material, Marlex 6002, manufactured by Phillips Petroleum. All test specimens were single lap shear specimens prepared from  $4 \times 1 \times 0.060$ " polyethylene coupons. Overlaps of  $\frac{1}{2}$ " were used. After bonding, all specimens were permitted to cure 72 hours at ambient temperature (23°C), then post cured at 49°C for four hours. They were then conditioned at 23°C and 50% RH for at least 24 hours before testing.

### **Epon 828 Versamid 140 Adhesive System**

Specimens were prepared by applying adhesive to both bonding surfaces of the treated polyethylene coupons and properly mating the halves. Each specimen was weighted with a 0.42-lb weight throughout the cure cycle.

### **Laminac 4116 4134 Adhesive System**

Specimens were prepared as described above except that they were not weighted during the cure cycle.

### **Pliobond 30 Adhesive System**

Specimens were prepared in the same manner as the Laminac specimens, but the adhesive was allowed to become tacky before the coupons were mated.

## **Testing**

All specimens were tested at room temperature on a Baldwin tensile test machine using the 1200-lb load cell and a 1200 lb/min load rate.

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